

This Page Is Inserted by IFW Operations
and is not a part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

IMAGES ARE BEST AVAILABLE COPY.

**As rescanning documents *will not* correct images,
please do not report the images to the
Image Problem Mailbox.**

C99



Consommation et
Affaires commerciales Canada

Consumer and
Corporate Affairs Canada

Bureau des brevets

Patent Office

Ottawa, Canada
K1A 0C9

(11) (C) 2,015,460

(22) 1990/04/26

(43) 1991/10/26

(45) 1993/12/14

(52) 166-33

5,079,3/96

(51) INTL.CL. ⁵ E21B-043/16

(19) (CA) **CANADIAN PATENT** (12)

(54) **Process for Confining Steam Injected Into a Heavy Oil Reservoir**

(72) Kisman, Kenneth E. , Canada

(73) **Alberta Oil Sands Technology and Research Authority , Canada**

(57) **5 Claims**

Canada

CCA 3254 (10-92) 41 7530-21-608-3254

2015460

1 "PROCESS FOR CONFINING STEAM INJECTED INTO
2 A HEAVY OIL RESERVOIR"

3 ABSTRACT OF THE DISCLOSURE

4 The process is practised in the context of a first
5 pattern of wells completed in a first portion of a heavy oil
6 reservoir. The first pattern has undergone steaming and
7 production and the underlying reservoir portion is significantly
8 depleted. A second pattern of wells is completed in a second
9 less-depleted portion of the reservoir. The two reservoir
10 portions are adjacent and in fluid communication. This may be
11 through a laterally extending thief zone high in the reservoir,
12 the thief zone having higher permeability to steam than the main
13 body of the reservoir. Steam injected into the second portion
14 thus will be lost into the depleted portion. The process
15 comprises injecting non-condensable gas into the depleted portion
16 while steaming and producing oil from the less-depleted second
17 portion. The gas is injected at a rate sufficient to maintain
18 the pressure in the two reservoir portions about equal. As a
19 result, the loss of steam to the depleted portion is inhibited.

2015460

4/1

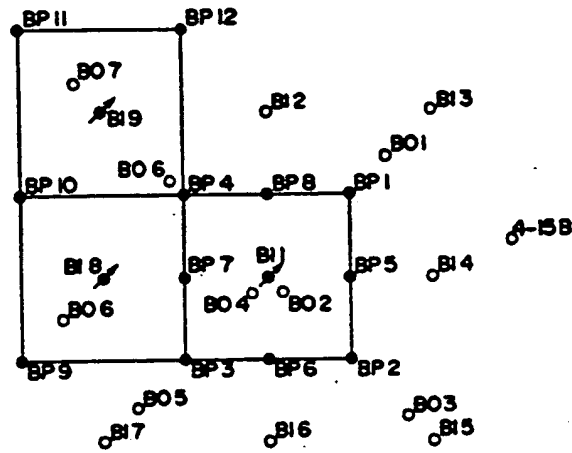
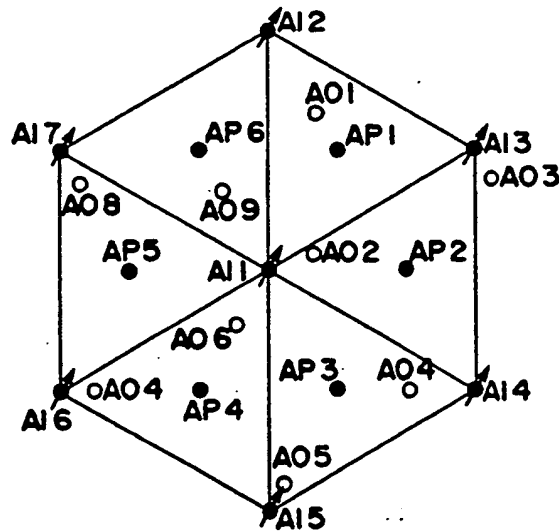


Fig. 1

A-15C



13-10

LEGEND

PRODUCER.....●
INJECTOR...../●
OBSERVATION...○

B

2015460

4/2

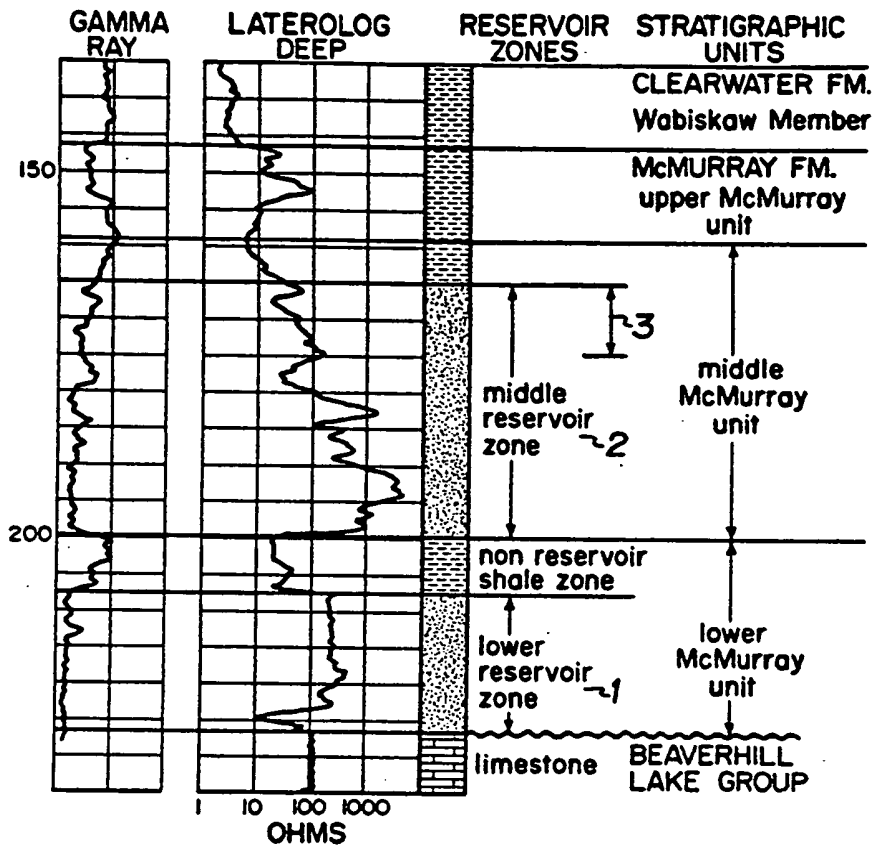


Fig. 2.

B

2015460

4/3

CANTERRA/ESSO/AOSTRA A.T.S. PILOT

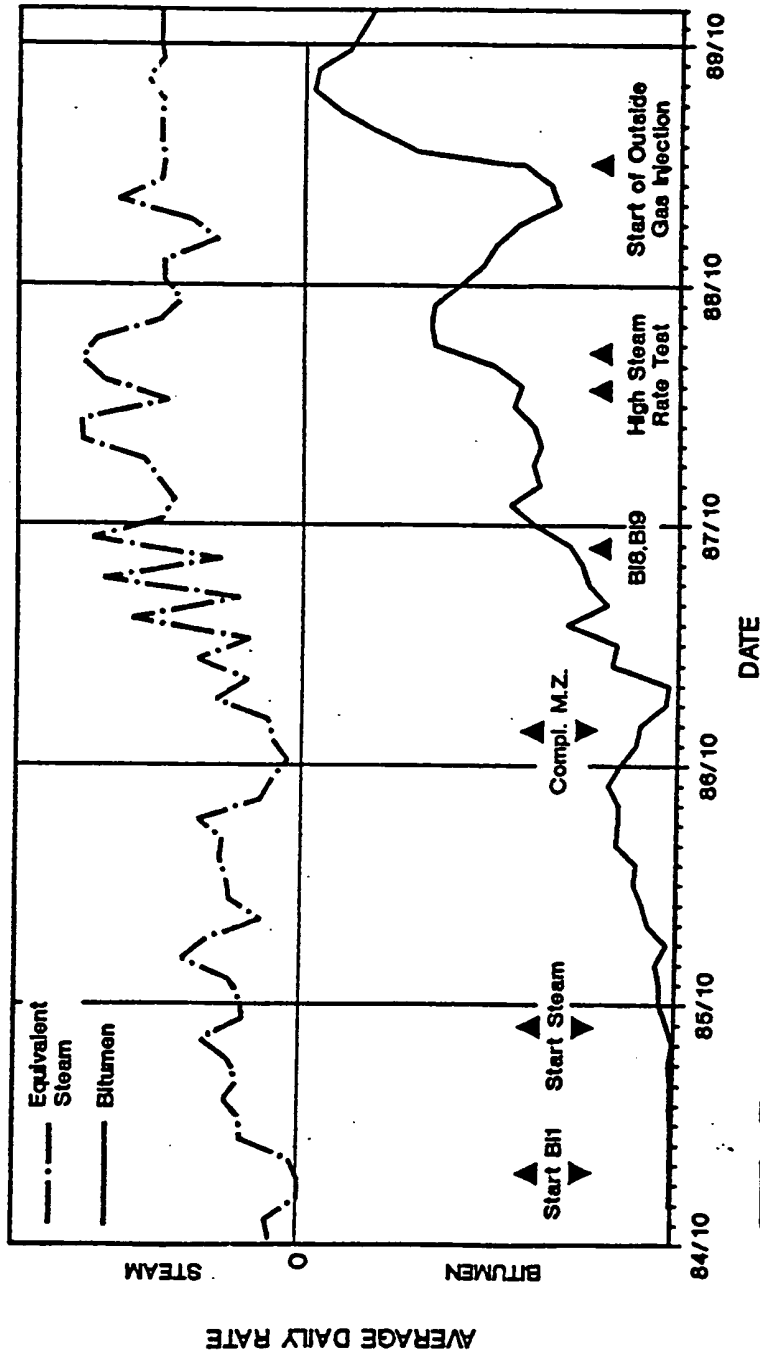


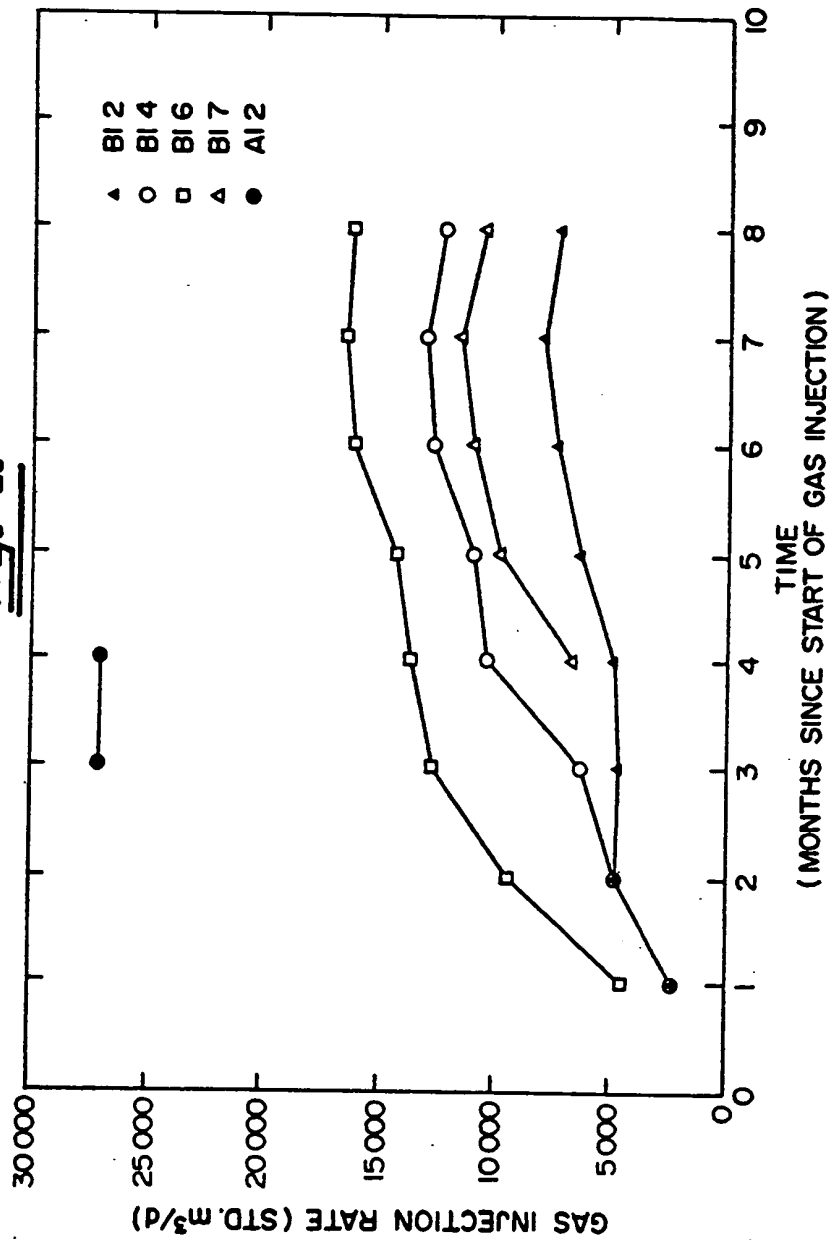
Fig. 3.

B

2015460

4/4

Fig. 4.



1 Field of the Invention

2 This invention relates to an improvement of a steam
3 injection process for the recovery of heavy oil. More
4 particularly, it relates to injecting non-condensable gas into
5 a depleted portion of a reservoir to pressure it up and prevent
6 the escape of steam thereinto, which steam is being injected into
7 an adjacent portion of the reservoir.

8 BACKGROUND OF THE INVENTION

9 It is conventional practice to inject steam into a
10 heavy oil reservoir to heat the formation and reduce the
11 viscosity of the oil, thereafter producing the oil once its
12 mobility has been improved. Such an operation is commonly
13 referred to as a "thermal project".

14 A problem can arise with respect to a thermal project
15 if a "thief zone" is in communication with the oil reservoir into
16 which the steam is being injected. If this is the case, the
17 injected steam will preferentially move into the thief zone.
18 Heating of the oil-saturated portion of the reservoir is then
19 reduced.

20 Frequently the thief zone is a laterally extending
21 section of that portion of the oil-containing reservoir that is
22 to be heated. The section typically will have a relatively high
23 gas or water saturation. Often it is located at the top of or
24 high in the reservoir.



1 A thief zone can also occur in another manner. In
2 heavy oil thermal projects it is common procedure to practice
3 steam injection and oil production in a first area and, when the
4 reservoir underlying the area is significantly depleted, to then
5 expand the project by commencing operations in an adjacent second
6 area. In some cases, the depleted first portion of the reservoir
7 is in fluid communication with the non-depleted second portion
8 of the reservoir. In this situation, steam injected into the
9 non-depleted portion of the reservoir may migrate into the
10 depleted portion. As a result, the depleted first portion of the
11 reservoir constitutes a thief zone for steam being injected into
12 the second portion.

13 When steam escapes into such a thief zone, it is found
14 that injection pressure diminishes and the temperature in the
15 producing portion of the reservoir is relatively low. As a
16 result, the oil production rate also drops off.

17 There is therefore a need for a process that will
18 inhibit losses of injected steam through or into a thief zone.

19 SUMMARY OF THE INVENTION

20 This embodiment of the invention is concerned with a
21 situation where there are two adjacent steam injection and fluid
22 production patterns, both completed in the same reservoir. The
23 reservoir portion underlying the first pattern has already
24 experienced some steam injection and oil production. Thus it is

1 partially depleted. The reservoir portion underlying the second
2 pattern has experienced less depletion. There is fluid
3 communication between the patterns - stated otherwise, steam
4 injected through the wells of the second pattern will enter the
5 more depleted reservoir portion.

6 In accordance with the invention, non-condensable gas
7 is injected through wells of the first pattern into the more
8 depleted reservoir portion at the same time that steam is
9 injected through wells of the second pattern. Preferably the
10 non-condensable gas is injected at a rate and in an amount
11 sufficient to substantially equalize the pressure in the more
12 depleted reservoir portion with the pressure in the steam zone
13 in the second reservoir portion. When this is done, steam loss
14 into the more depleted portion of the reservoir is inhibited with
15 a concomitant improvement in oil production and steam/oil ratio
16 at the second pattern. The gas injected into the first pattern
17 may also contribute to improved performance in the production
18 wells within the first pattern.

19 DESCRIPTION OF THE DRAWINGS

20 Figure 1 is a schematic showing the patterns and the
21 gas injection wells which were used in demonstrating the
22 invention at a pilot project;

23 Figure 2 illustrates with logs the nature of the
24 reservoir in the pilot test area;

1 Figure 3 is a plot showing st am injection and bitumen
 2 production rates for the B pattern of the pilot test. Arrows on
 3 th plot indicat when the injection well BI1 was started up,
 4 when BI1 injection was switched from hot water to steam, when the
 5 middle zone was completed, when injection wells BI8 and BI9 were
 6 started up, when the high steam rate test was conducted, and when
 7 outside gas injection began; and

8 Figure 4 is a plot of gas injection rate through the
 9 wells identified on the plot.

10 DESCRIPTION OF THE PREFERRED EMBODIMENT

11 The invention is exemplified by the following example
 12 based on a pilot test conducted in the Kearl Lake region of
 13 Alberta.

14 The reservoir at the pilot site, depicted in Figure 2,
 15 has two oil producing pay zones, a lower zone 1 and a middle zone
 16 2. The middle pay zone 1 is approximately 35 m thick and has a
 17 sand region 3 at its upper end. This region 3 is approximately
 18 10 m thick and has significantly higher water saturation than the
 19 pay zone 2. The region 3 constitutes a thief zone for steam
 20 injected through well perforations in the pay zones 1,2.

21 The bitumen in the pay zone 2 is effectively immobile
 22 at initial reservoir conditions.

23 A steam drive pilot was initiated in an A pattern
 24 consisting of steam injection wells and production wells. The
 25 layout of the A pattern wells is shown in Figure 1. Each well

1 is identified as to pattern (A), nature (injection (I),
2 production (P), or observation (O)) and number. The A pattern
3 was an inverted 7-spot with peripheral steam injection to enclose
4 the pattern and make it equivalent to an inner pattern in a
5 commercial project. The pattern covered 5.37 acres.

6 At the same time that the A pattern was drilled, an
7 adjacent B pattern was also drilled. The B pattern was
8 originally an inverted 5-spot surrounded by 8 steam injection
9 wells. It was decided to delay start-up of the B pattern to gain
10 operating experience on the A pattern.

11 A steam drive was initiated in December, 1981, in the
12 A pattern and continued for 5 years. Steam was injected into the
13 AI wells and fluid was produced from the AP wells.

14 It became clear that a large volume of steam was being
15 lost from the A pattern, as the steam-oil ratio was very high.

16 As a result of the A pattern experience, changes were
17 made to the B pattern prior to its start-up. It was decided not
18 to inject steam into the peripheral wells of the B pattern.
19 Instead the B pattern was converted from a 5-spot to a 9-spot.

20 Start-up of the BI1 pattern occurred in February, 1985,
21 and start-up of the patterns of BI8 and BI9 was initiated in
22 September, 1987. Steam was injected through the 3 injection
23 wells and fluid produced from the 12 production wells in
24 conventional fashion.

25 Wells BI2, BI3, BI4, BI5, BI6 and BI7 were also
26 completed in the reservoir as observation wells and were used to
27 monitor temperature and pressure outside the B pattern.

1 Th chronology of op rations in the B pattern and the
2 eff ct on bitumen production is shown in Figur 3. Hot wat r
3 inj ction was initiated into the lower zon 1 of th BI1 pattern
4 in February, 1985. Steam injection into the lower zone 1 of the
5 BI1 pattern began in August, 1985. Middle zone 2 operations
6 began in December, 1986. The BI8 and BI9 patterns were added in
7 September, 1987.

8 A high rate steam test was conducted in the summer of
9 1988 in which the steam injection rate was approximately doubled
10 for a period of about two months.

11 The outside gas injection test was begun in April,
12 1989, with the injection of natural gas into wells BI2, BI4 and
13 BI6 following perforation of those wells in the region 3 of the
14 middle zone 2. Gas injection into wells BI7 and AI2 was
15 initiated a few months later, as shown in Figure 4.

16 As shown in Figure 3, the high rate steam test resulted
17 in a significant increase in bitumen production rates, but the
18 steam-oil ratio did not improve.

19 After the high rate steam test, the bitumen production
20 rate fell considerably until March, 1989, when the steam
21 stimulation of some production wells began in anticipation of
22 the outside gas injection test.

23 As stated, the outside gas injection test began in
24 April 1989, and is still continuing. Gas injection was conducted
25 simultaneously with steam injection. More particularly, during
26 the outside gas injection test, the steam injection rate was held
27 constant at a rate of only about 60% of that during the high rate
28 steam test. The bitumen production rate during the outside gas
29 injection test

1 started to incr as significantly within one month, and, ver th
2 ight month period since gas injection began, the bitumen
3 production rat has, on average, b n mor than 80% high r than
4 that prior to gas inj ction.

5 The instantaneous steam-oil ratio during the outside
6 gas injection test also improved considerably over that observed
7 prior to outside gas injection.

8 No detrimental effects of outside gas injection have
9 been observed. There has been no noticeable increase in gas
10 production at the production wells. The injected gas remains
11 near the top of the payzone 2 due to gravity effects, while
12 liquids are produced through perforated intervals near the base
13 of the pay zone.

14 Prior to outside gas injection, the region 3 allowed
15 fluids to flow out of the B Pattern. In particular, steam, hot
16 water and hot bitumen flowed out of the B pattern during steam
17 injection within the pattern. This was evidenced by temperature
18 and pressure measurements at the observation wells outside the
19 pattern and by the fact that the pressure within the pattern
20 remained low. When the steam injection rate was increased in the
21 B pattern, a temperature response could be detected even within
22 the A pattern. Thus the A pattern constituted a thief zone in
23 communication with the B pattern.

24 At the time gas injection began into region 3 through
25 wells outside the B pattern, the pressure within the B pattern
26 was only about 800 kPa. The native reservoir pressure is about

1 300 kPa. Within three months of the commencement of outside gas
2 injection, the pressure within the B pattern increased from 800
3 kPa to over 1000 kPa and the pressure within the A pattern
4 increased from about 400 kPa to over 900 kPa. Within the B
5 pattern, the temperature increased along with the pressure as
6 determined by saturated steam conditions within the B pattern.

7 Prior to and during the outside gas injection
8 operation, wells AP1 and AP3 and AP6 were maintained on
9 production even though no steam was injected into any wells in
10 the A pattern. Prior to the commencement of outside gas
11 injection, the A pattern wells benefitted from heat communication
12 with the B pattern but this heat communication was eliminated
13 when gas injection began. Even though the A pattern wells lost
14 heat communication, the production performance of wells AP1, AP3
15 and AP6 has increased over that prior to gas injection. This
16 increased production is believed to be related to an improved
17 gravity drainage mechanism due to the increased gas saturation
18 in the A pattern.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method for recovering heavy oil that is effectively immobile at reservoir conditions, from a reservoir having a partially-depleted portion penetrated by a first pattern of wells and an adjacent less-depleted portion penetrated by a second pattern of steam injection and oil production wells which are completed in said less-depleted portion, the less-depleted portion of the reservoir being in fluid communication with the partially-depleted portion, comprising:

injecting steam into the less-depleted portion of the reservoir through the injection wells of the second pattern, to heat the oil in said portion and render it mobile;

simultaneously injecting non-condensable gas, through at least one well of the first pattern, into the partially-depleted portion of the reservoir at a rate and in an amount sufficient to maintain the pressure in the partially-depleted portion at the gas injection wells about equal with the pressure in the reservoir portion underlying the second pattern and undergoing steam injection; and

producing heated oil from the second pattern.

2. The method as set forth in claim 1 wherein:

the non-condensable gas injected is selected from the group consisting of natural gas, flue gas and carbon dioxide.

2015460

3. The method as set forth in claim 2 wherein:

the production wells of the second pattern are perforated low in the payzone of the reservoir.

4. The method as set forth in claim 3 wherein:

the reservoir portions are in fluid communication through a thief zone high in the reservoir.

5. The method as set forth in claim 1 wherein:

the reservoir portions are in fluid communication through a thief zone high in the reservoir; and

steam and gas injection are continued simultaneously after heat breakthrough at the production wells of the second pattern.

